1.1 Inertia and Frames of Reference

SECTION EXPECTATIONS

- Describe and distinguish between inertial and non-inertial frames of reference.
- Define and describe the concept and units of mass.
- Investigate and analyze linear motion, using vectors, graphs, and free-body diagrams.

KEY TERMS

- inertia
- inertial mass
- gravitational mass
- coordinate system
- frame of reference
- inertial frame of reference
- non-inertial frame of reference
- fictitious force

Imagine watching a bowling ball sitting still in the rack. Nothing moves; the ball remains totally at rest until someone picks it up and hurls it down the alley. Galileo Galilei (1564–1642) and later Sir Isaac Newton (1642–1727) attributed this behaviour to the property of matter now called **inertia**, meaning resistance to changes in motion. Stationary objects such as the bowling ball remain motionless due to their inertia.

Now picture a bowling ball rumbling down the alley. Experience tells you that the ball might change direction and, if the alley was long enough, it would slow down and eventually stop. Galileo realized that these changes in motion were due to factors that interfere with the ball's "natural" motion. Hundreds of years of experiments and observations clearly show that Galileo was correct. Moving objects continue moving in the same direction, at the same speed, due to their inertia, unless some external force interferes with their motion.

Figure 1.1 You assume that an inanimate object such as a bowling ball will remain stationary until someone exerts a force on it. Galileo and Newton realized that this "lack of motion" is a very important property of matter.

Analyzing Forces

Newton refined and extended Galileo's ideas about inertia and straight-line motion at constant speed — now called "uniform motion."

NEWTON'S FIRST LAW: THE LAW OF INERTIA

An object at rest or in uniform motion will remain at rest or in uniform motion unless acted on by an external force.

Newton's first law states that a force is required to *change* an object's uniform motion or velocity. Newton's second law then permits you to determine how great a force is needed in order to change an object's velocity by a given amount. Recalling that acceleration is defined as the change in velocity, you can state Newton's second law by saying, "The *net* force ($\vec{F}$) required to accelerate an object of mass m by an amount ($\vec{a}$) is the product of the mass and acceleration."

NEWTON'S SECOND LAW

The word equation for Newton's second law is: Net force is the product of mass and acceleration.

$$\vec{F} = m\vec{a}$$

Quantity	Symbol	SI unit
force	$\vec{F}$	N (newtons)
mass	m	kg (kilograms)
acceleration	$\vec{a}$	$\frac{\text{m}}{\text{s}^2}$ (metres per second squared)

Unit analysis

$$\text{(mass)(acceleration)} = \text{(kilogram)}\left(\frac{\text{metres}}{\text{second}^2}\right) \text{kg}\frac{\text{m}}{\text{s}^2} = \frac{\text{kg}\cdot\text{m}}{\text{s}^2} = \text{N}$$

Note: The force ($\vec{F}$) in Newton's second law refers to the vector sum of all of the forces acting on the object.

LANGUAGE LINK

The Latin root of *inertia* means "sluggish" or "inactive." An *inertial guidance system* relies on a gyroscope, a "sluggish" mechanical device that resists a change in the direction of motion. What does this suggest about the chemical properties of an *inert gas*?

Inertial Mass

When you compare the two laws of motion, you discover that the first law identifies inertia as the property of matter that resists a change in its motion; that is, it resists acceleration. The second law gives a quantitative method of finding acceleration, but it does not seem to mention inertia. Instead, the second law indicates that the property that relates force and acceleration is mass.

Actually, the mass (m) used in the second law is correctly described as the **inertial mass** of the object, the property that resists a change in motion. As you know, matter has another property — it experiences a gravitational attractive force. Physicists refer to this property of matter as its **gravitational mass.** Physicists never assume that two seemingly different properties are related without thoroughly studying them. In the next investigation, you will examine the relationship between inertial mass and gravitational mass.